

Cost Savings of a Multi-Gas Climate Policy*

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March 16, 2007

1 Introduction

This short note completes the work done in [5] and analyzes for Switzerland the benefits of a multi-gas greenhouse gas (GHG) abatement strategy. Appendix A provides the modeling framework for non CO₂ GHG in the GEMINI-E3 model [1].

2 Scenarios

On top of the reference scenario as presented in [5], we consider two additional scenarios: in the first scenario (*Kyoto2020GHG*), Switzerland reaches the same GHG abatement as in scenario *Kyoto2020* (see [5]) but this target is obtained through a multi-gas strategy in which all GHG emissions are taxed. All gases are converted to CO₂-equivalent based on the 100-year Global Warming Potentials (GWPs). In the second scenario (*Kyoto2050GHG*), we applied the same methodology but we used the same target as in the scenario *Kyoto2050*. Comparing the

*The authors gratefully acknowledge the support of the Swiss Federal Office for the Environment, Federal Office of Energy and Swiss National Centre of Competence in Research on Climate (NCCR-Climate)

scenarios *Kyoto2020GHG* and *Kyoto2050GHG* with the previous scenarios allows assessing the benefits of a multi-gas strategy. Assumptions concerning international environment (energy prices, climate policies in other regions, etc) are constant across scenarios.

2.1 Scenario Kyoto2020GHG

In this scenario, Switzerland reduces its emissions by 20% (compared to 1990 level) by the year 2020. Table 1 presents the simulation results : the CO₂ tax and the welfare cost associated with scenarios Kyoto2020 and Kyoto2020GHG. When a multi-gas strategy is implemented the cost of abatement is significantly reduced. The CO₂ tax in 2020 is reduced by 28% and the welfare cost is reduced by 42% to 1 850 millions CHF.

Table 1: Tax and Welfare Cost in Switzerland

	2010	2020
Tax in CHF ₂₀₀₁		
CO ₂ tax (<i>Kyoto2020</i>)	111	790
GHG tax in eq. CO ₂ (<i>Kyoto2020GHG</i>)	58	570
Welfare effect in millions CHF		
<i>Kyoto2020</i>	-288	-3'211
<i>Kyoto2020GHG</i>	-50	-1'850
Welfare effect as % of total household consumption		
<i>Kyoto2020</i>	-0.10%	-1.01%
<i>Kyoto2020GHG</i>	-0.02%	-0.58%

Table 2 provides the GHG emissions abatement for both 2020 scenarios. Non CO₂ GHG emissions are already lower in the Kyoto2020 scenario than in the base-line scenario due to the slowdown in the energy sectors caused by the abatement of CO₂ emissions. Similarly, the non CO₂ GHG emissions in the agriculture sector are also reduced due to a slight decrease in agriculture production in Switzerland. These abatements are nevertheless reinforced in the multi-gas scenario, where the abatement of High GWP gases reaches 40%, methane is reduced by 38% and nitrous oxide is reduced by 26%.

Table 2: GHG emissions abatement in 2020		
	<i>Kyoto2020</i>	<i>Kyoto2020GHG</i>
CO ₂	-31%	-27%
Methane	-7%	-38%
Nitrous Oxide	-3%	-26%
High GWP gases	-1%	-40%
Total GHG	-28%	-28%

2.2 Scenario Kyoto2050GHG

This second scenario is similar to the previous one when it comes to the targets from 2006 to 2020, but it assumes strong reduction of 10% per decade after the year 2020 and until 2050. Table 3 compares from 2020 to 2050 the taxes and the welfare costs in the pure CO₂ abatement scenario with the multi-gas scenario. As expected the results are analogous to those of the scenario *Kyoto2020GHG*. In 2050, the tax would be reduced by 24% and the welfare cost would be reduced by approximately 2,5 billion CHF. Nevertheless, when the abatement effort is increased, the benefits of a multi-gas policy are decreasing in relative terms. In 2020, a 28% abatement in GHG emission, using the multi-gas strategy, leads to a reduction of the welfare costs of 42%. In 2050, for an abatement of 45%, the multi-gas policy only allows for saving 27% of the welfare costs. This highlights the fact that the abatement potential of non CO₂ GHG is limited and they take a relatively smaller part in the total effort when substantial emission reductions are required.

Table 3: Tax and Welfare Cost in Switzerland				
	2020	2030	2040	2050
Tax in CHF ₂₀₀₁				
CO ₂ tax (<i>Kyoto2050</i>)	790	1'061	1'568	2'429
GHG tax in eq. CO ₂ (<i>Kyoto2050GHG</i>)	570	782	1'180	1'841
Welfare cost in millions CHF				
<i>Kyoto2050</i>	-3'211	-4'287	-6'209	-9'117
<i>Kyoto2050GHG</i>	-1'850	-2'699	-4'238	-6'599
Welfare cost as % of total households consumption				
<i>Kyoto2050</i>	-1.01%	-1.22%	-1.56%	-2.00%
<i>Kyoto2050GHG</i>	-0.58%	-0.77%	-1.06%	-1.45%

Table 4 provides the GHG emissions abatement for both 2050 scenarios. It shows that non CO₂ GHG emission are reduced even when they are not directly taxed due to the slowdown of key emitting sectors. Nevertheless, abatement is much stronger when those gases are also taxed.

Table 4: GHG emissions abatement in 2050		
	<i>Kyoto2050</i>	<i>Kyoto2050GHG</i>
CO ₂	-49%	-45%
Methane	-13%	-51%
Nitrous Oxide	-10%	-40%
High GWP gases	-1%	-43%
Total GHG	-45%	-45%

3 Conclusion

These results are in line with existing studies on multi-gas mitigation (see [2] and [18]). The inclusion of non CO₂ GHG in the scenarios reduces significantly the carbon price and the welfare cost. Figure 1 shows the CO₂ tax in Switzerland for both *Kyoto2050* and *Kyoto2050GHG* scenarios. The multi-gas approach allows for a lower tax to reach similar targets and the difference between the two taxes is growing over time. In 2050, the welfare cost reduction due to the inclusion of other gases is estimated to about 27%. The importance of non CO₂ GHG abatement is nevertheless limited when substantial emission reductions are required due to the limited potential of reduction of those gases.

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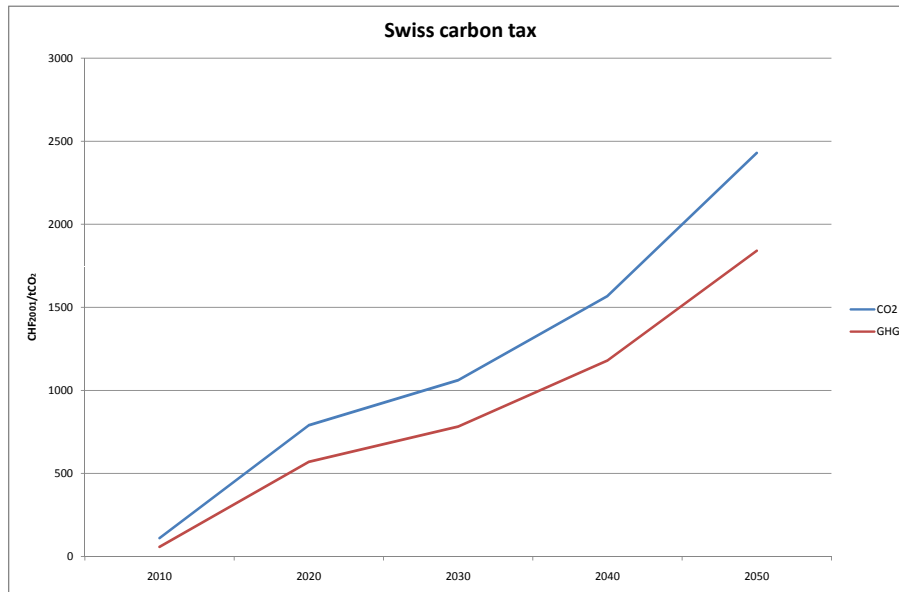


Figure 1: Comparison of the evolution of the CO₂ tax in Switzerland (CO₂ only and multi-gas).

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A Modeling non carbon GHG

A.1 Emission of non carbon GHG

We take into account all the direct GHGs covered by the United Nations Framework Convention on Climate Change (UNFCCC) : Methane, nitrous oxide, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF₆) (the last three gases are called the high global warming potential gases). Emissions of non carbon greenhouse gas emissions are converted to a CO₂-equivalent based on the 100-year Global Warming Potentials (GWPs) defined by the Intergovernmental Panel on Climate Change [7]. Historical estimates are reported for 1990, 1995 and 2000 and projections of emissions are provided for 2005, 2010, 2015 and 2020 (see [16, 10]¹). Historical and projected emissions are mainly based on national inventory compiled by each nation and submitted to UNFCCC Secretariat [12, 11], but national reports are also used. When no emissions data are available or data are insufficient, EPA estimates emissions or projections using the methodologies presented in the IPCC Guidelines². The EPA projections represent the business as usual scenario where currently achieved reductions are incorporated and future mitigation actions are included only if either a well established program or an international sector agreement is in place.

A.1.1 Methane

The model takes into account 13 sources of CH₄ emissions. The emissions of each source are linked to an activity level (or an economic driver) the coefficient of which is calibrated on the baseline scenario:

$$NCO2_{lr} = \frac{\nu_{lr}}{\theta_{lr}^t} \cdot ED_{lr} \quad (1)$$

where ED_{lr} is the economic driver, ν_{lr} a coefficient representing the amount of source l emitted by the economic driver and θ_{lr} an exogenous technical progress on the coefficient ν_{lr} .

¹The data compiled by Environmental Protection Agency can be found on U.S. EPA's webpage at <http://www.epa.gov/nonco2/econ-inv/international.html>.

²This is often the case for high GWP gases.

Table 5: Methane and GEMINI-E3 activities

Source	Index (I) ^a	Economic Drivers	MAC
Landfilling of Solid Waste	LAN	Total Household Consumption	Yes
Biomass Combustion	BIC	Total Household Consumption	
Fugitives from Coal Mining Activities	COA	Agriculture Production	Yes
Enteric Fermentation	ENT	Agriculture Production	Yes
Stationary and Mobile Combustion	FUE	Total Demand of Refined Petroleum	
Other Industrial Non-Agricultural Sources	IND	Chemical Production	
Oil	OIL	Crude Oil Production	Yes
Manure Management	MAN	Agriculture Production	Yes
Rice Cultivation	RIC	Agriculture Production	Yes
Other Agricultural Sources	OAG	Agriculture Production	Yes
Wastewater	WAS	Total Household Consumption	
Other Non-Agricultural Sources (Waste & Other)	OTH	Total Household Consumption	
Natural gas	GAS	Total Demand of Natural Gas	Yes

^a for example the index in the case of emissions coming from coal mining is noted CH_4^{Coa}

Table 6: Nitrous oxide and GEMINI-E3 activities

Source	Index (I) ^a	Economic Drivers	MAC
Agricultural Soils	AGS	Agriculture Production	Yes
Other Agricultural Sources	OAG	Agriculture Production	Yes
Biomass Combustion	BIC	Total Household Consumption	
Stationary and Mobile Combustion	FUE	Total Demand of Refined Petroleum	
Manure Management	MAN	Agriculture Production	Yes
Other Non-Agricultural Sources (Waste & Other)	OTH	Total Household Consumption	
Other Industrial Non-Agricultural Sources	OIN	Metal and Metal Goods Production	
Adipic Acid Production	ADI	Chemical Production	Yes
Nitric Acid Production	NIT	Chemical Production	Yes
Human Sewage	HUM	Total Household Consumption	

^a for example the index in the case of emissions coming from adipic acid production is noted N_2O^{Adi}

The table 5 shows the correspondence between the sources and the sectors/products in GEMINI-E3, the variable of the model representing the economic driver, and whether an abatement curve (MAC) is available for this source.

A.1.2 Nitrous oxide

For N_2O emissions we adopt the same formulation and the table 6 gives the economic driver for the 10 sources of emission.

A.1.3 High global warming potential gases

High global warming potential gas emissions result from the use of substitutes for ozone-depleting substances, from the production of magnesium, aluminum, semiconductors, flat panel display, HCFC-22, electrical equipment and from the

Table 7: High global warming potential gases and GEMINI-E3 activities

Source	Index (<i>l</i>)	Economic Drivers	MAC
ODS Substitutes Aerosols (Non-MDI)	PFC_AEN	Total Household Consumption	Yes
ODS Substitutes Fire Extinguishing	PFC_FIR	Total Household Consumption	Yes
ODS Substitutes Foams	PFC_FOA	Total Household Consumption	Yes
ODS Substitutes Solvents	PFC_SOL	Total Household Consumption	Yes
ODS Substitutes Aerosols (MDI)	PFC_AEM	Total Household Consumption	Yes
ODS Substitutes Refrigeration/Air Conditioning	PFC_REF	Total Household Consumption	Yes
HFC-23 Emissions from HCFC-22 Production	HFC_22	Total Household Consumption	Yes
SF6 Emissions from Electric Power Systems	SF6_EPS	Metal and Metal Goods Production	Yes
PFC Emissions from Primary Aluminum Production	PFC_PAP	Metal and Metal Goods Production	Yes
HFC, PFC, SF6 from Semiconductor Manufacturing	PFC_SEM	Equipment Goods Production	Yes
SF6 Emissions from Magnesium Manufacturing	SF6_MAM	Metal and Metal Goods Production	Yes

use of electrical equipment. GEMINI-E3 distinguishes 11 types of fluorinated gases, they are presented in table 7.

A.2 Abatement cost

Concerning the mitigation option analysis [17] the methodologies are based mainly on [4, 9, 3]. The first part of their analysis is to establish a list of mitigation options for each gas by source category from existing engineering and/or economic studies. Extensive information is available concerning USA and European countries and the major developed regions (see [6, 8, 13, 14, 15]). Each abatement option is then characterized in terms of its costs and benefits per abated ton, the costs include capital and operation & maintenance costs. The cost of abatement are adjusted across regions and take into account mainly the difference in labor costs. The benefits include the abated gas multiplied by the carbon tax and sometimes revenues coming from the sale of a byproduct linked to the abated gas or from the sale of the gas itself (for example sales of methane as an energy input). A present value analysis of each option is then used to determine break-even abatement costs for each option. The result of the analysis is marginal abatement costs (MACs) indicating the potential reduction in non-carbon gas emissions for a given break-even price. These curves have the generic form described in figure 2.

We can then compute the level of emissions on the basis of a CO₂ tax:

$$NCO2_{lr} = \frac{v_{lr}}{\theta_{lr}^t} \cdot [1 - f_{lr}(TCO2_r)] \cdot ED_{lr} \quad (2)$$

where $f_{lr}(TCO2_r)$ is a linear approximation of the abatement curve given by [17].

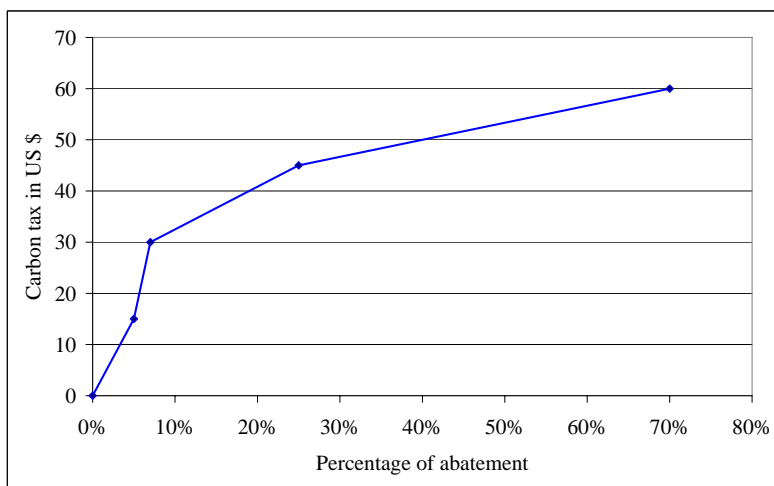


Figure 2: Curve of marginal abatement costs.